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IONIZATION CHAMBER SMOKE DETECTORS
Questions and Answers

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Canada

IONIZATION CHAMBER SMOKE DETECTORS

Questions and Answers

The smoke detector is a modern safety device found in many Canadian homes. As part of municipal fire-prevention programs, some communities have even required their installation by law.

One kind of smoke detector, the *ionization-type*, is regulated by the Atomic Energy Control Board (AECB) because it uses a radioactive substance in its mechanism.

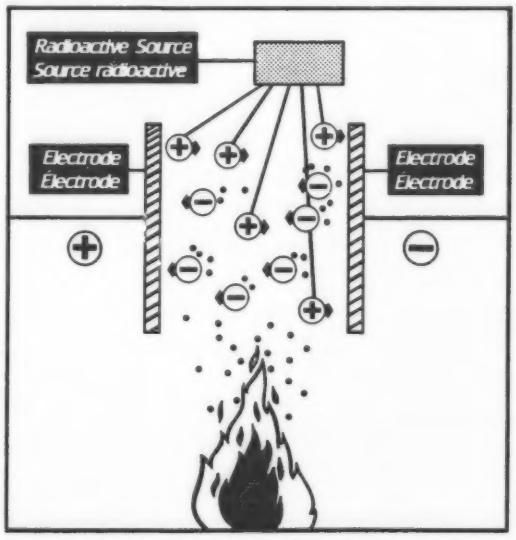
When opening this style of detector for installation or to change the battery, householders discover, often for the first time, that their device contains a radioactive material - a prominent label on the inner housing bears the three-bladed radiation warning symbol and a cautionary message.

Radioactivity and radiation are natural phenomena, but they are not very familiar to the average householder. This has led to a number of questions being asked of the AECB:

Why is a radiation source used in smoke detectors?

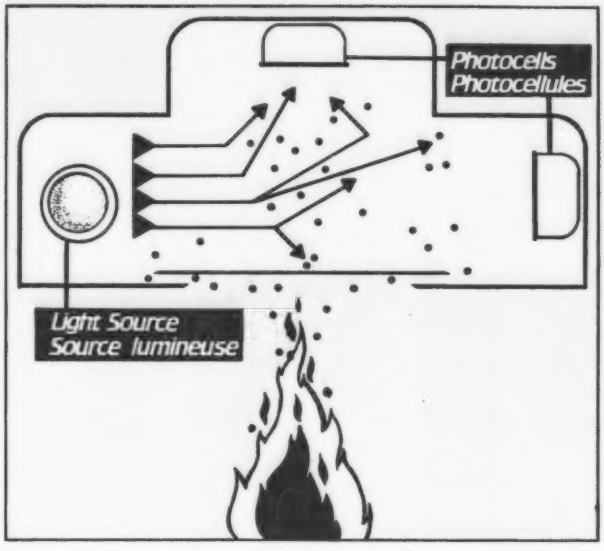
The radiation source in an ionization chamber smoke detector makes it highly sensitive to changes in air quality, allowing it to set off an alarm. A tiny amount of radioactive material - most frequently the metal americium-241 - is used to "ionize" the air in the detector chamber. Becoming electrically charged by the action of the radiation, the air in the chamber is transformed into a conductor of electrical current between two electrodes.

When smoke particles enter the detector, the ionized air is affected, the electrical current is changed, and the alarm is triggered as a result.



Are there smoke detectors that don't use a radiation source?

Yes. Photoelectric detectors have a lamp or other light source inside their casing that directs a beam of light into a chamber. The detector contains a light-sensitive photocell that is not in line with the lamp and therefore doesn't pick up the light. But when smoke particles enter the chamber, the particles scatter the light beam and the photocell detects the reflected light. An alarm is then sounded.



Which smoke detector type is best?

Independent tests have shown that each type has its strengths and weaknesses. Ionization detectors respond particularly well to the smoke generated by a flaming fire. They are not as sensitive, however, to smoke from a smouldering fire.

Photoelectric detectors are sensitive to smoke from smouldering fires but react relatively slowly to flaming fires -- the reverse of the ionization-type detectors.

After testing different models and consulting with various fire departments, *Consumer Reports* magazine recommended that its readers install both types.

There are also smoke detectors on the market that contain both ionization and photoelectric sensors. These combination detectors aim to take advantage of the strengths of the two systems in a single unit.

If there is an alternative, why allow those that contain radioactive material at all?

As mentioned above, various tests have shown that photoelectric and ionization-type smoke detectors are not exactly equivalent in their response to products of combustion, and this could be a key factor in model selection by the consumer. For instance, it is obviously important to have an early reaction to a fast-burning fire, and this happens to be a characteristic of the ionization-type. In view of the enormous benefit as compared to negligible risk (see The risk/The benefits, pp. 8-9,) the sale of approved ionization chamber smoke detectors is justified.

How much radiation is emitted from an ionization chamber smoke detector?

So little radiation escapes from the smoke detector mechanism that it takes special measuring devices and techniques to distinguish it from the natural background radiation always present.

To ensure public safety, the manufacture and distribution of consumer devices like smoke detectors, television sets and luminous watches - all of which can emit radiation - is carefully regulated. Through a pre-sale approval process, such products are judged model by model against strict radiation emission standards. Under Canadian rules for smoke detectors, the maximum dose rate may not exceed 10 nanosievert (one microrem) per hour at a distance of one metre from the device. This maximum, which approved models seldom if ever reach, is roughly a tenth of the average level of natural background radiation. Whatever radiation is actually emitted decreases rapidly as the distance from the detector increases.

What type of radiation is emitted by the detector?

An americium-241 source gives off both alpha and gamma radiation. Alpha radiation consists of fast-moving, sub-atomic particles, while gamma radiation - often called gamma rays - is energy propagated as a wave, like the more-familiar x-rays.

Alpha particle emitters, if they are inhaled or ingested, can be harmful as their radiation continuously bombards sensitive internal tissue, but alpha radiation is not very penetrating. A single sheet of paper or a few centimetres of air can block an alpha particle. This form of radiation therefore does not pass out of the inner metal housing of a smoke detector.

Gamma radiation is more penetrating, and can travel further than alpha particles. However, very little gamma radiation is emitted by a smoke detector, and the radiation drops sharply with distance from the device. *Consumer Reports* magazine confirmed this by checking a series of smoke detectors with a Geiger counter. Even up close, the investigators could not distinguish any radiation above the background radiation that everyone is exposed to from the earth, building materials and outer space.

What radiation dose might a resident receive from an ionization-type detector?

If a person remained one metre from a detector for eight hours a day, after a year - assuming the device was emitting the maximum permissible radiation - the person would have received a dose from that source of less than 30 microsieverts (3 millirem). This dose is about the same as the extra radiation dose passengers receive on a transcontinental flight from the more abundant cosmic rays at high altitudes.

In the home, the actual radiation dose people receive from a detector mounted in its proper place is a great deal smaller and verges on zero. A study conducted by the Nuclear Regulatory Commission in the United States estimated that the average annual radiation dose received from an approved smoke detector is about 10,000 times less than the radiation dose due to natural background radiation.

But what about exposure to large numbers of smoke detectors at the same time?

In the same Nuclear Regulatory Commission study mentioned above, it was estimated that a retail clerk working near a display of 100 stacked ionization-type smoke detectors would receive hundreds of times less radiation from the stack than he or she receives from natural background radiation.

Can the radioactive source ever present a hazard?

In the unlikely event the metal casing holding the radiation source were opened and the source itself cut into small pieces, filed down, or melted - and then breathed or ingested - this would increase the risk of health problems for the individual involved, because sensitive internal tissue would be directly exposed to alpha radiation. While the source is in its customary location, however, the possibility of harm from it is negligible.

A smoke detector's radiation source is tightly bonded in a small, metallic "sandwich" of gold and silver, somewhat less than half the size of a dime. Gold is essentially insoluble and the foil therefore protects against the release of radioactive material if the source is somehow accidentally ingested.

The scientific journal *Health Physics* has documented a case of someone having accidentally swallowed a radiation source from a smoke detector. A female assembly-line worker took in two whole americium-241 radiation sources. The sources were excreted naturally within a number of weeks. Scientists carefully monitored the woman and examined the recovered sources. They concluded that the amount of radioactive material released from the sources while in her body "was not significant from the point of view of radiological protection".

What if there's a fire?
Won't that cause the release of hazardous radiation?

Studies were conducted to determine the answer to this question at the Oak Ridge National Laboratory in the United States. In the test, smoke detectors were subjected to conditions that would be present in the most severe fires - fires that reach a temperature of 1200°C (2200°F), hot enough to melt silver and gold. The detectors were exposed to this intense heat for a full hour.

It is doubtful that anyone could stay alive for long in such an intense fire and stand inside the blaze to inhale any released radioactive material. Nevertheless, the U.S. Nuclear Regulatory Commission calculated that after six minutes, and without any protective breathing apparatus, a resident could be exposed to enough radioactive material to result in a radiation dose of about 0.01 millisieverts (1 millirem). This is approximately one percent of the yearly dose a person receives from natural background radiation.

Are firefighters subjected to a greater risk?

Yes, from the fire, not the radiation. Firefighters would experience the same small level of risk from the radioactive source as described in the preceding answer unless they were wearing standard breathing apparatus, which would result in almost complete protection from airborne material.

The U.S. Nuclear Regulatory Commission has also estimated the radiation dose a firefighter might experience in the most severe conditions. If a firefighter battled a warehouse blaze where 1,000 ionization units were stored, the effort might result in his receiving a radiation dose of 23 microsieverts (2.3 millirem). The dose would arise from radioactive material inhaled after an hour's work in the smoke and heat, provided no air was escaping to the outside of the burning warehouse and the firefighter was wearing a reasonably efficient breathing apparatus that would allow him to stay for an hour in such an intense atmosphere. The radiation dose is less than you could get from a medical or dental x-ray.

But what about the smoke detector that's been damaged in the blaze? Does it pose a problem?

The tiny radiation source would either disappear in the rubble and be undetectable from the normal background radiation, or would remain contained in what was left of the smoke detector. (British studies indicate that a smoke detector tends to collapse in on itself in a fire.) The remains of the unit would be disposed of along with any other waste from the burnt building.

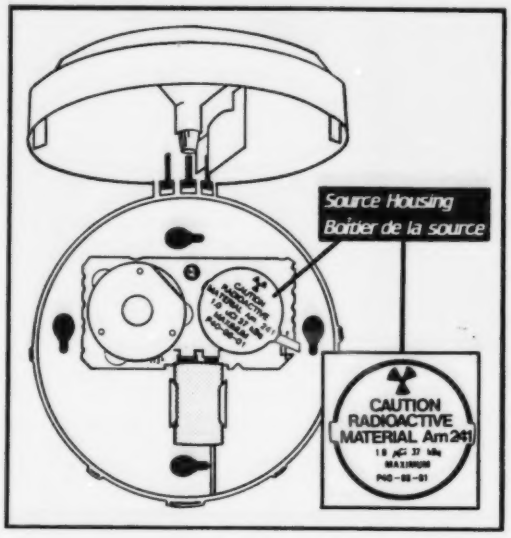
What are the safety rules governing smoke detectors?

Ionization chamber smoke detectors marketed in Canada must conform to the standards established by the Atomic Energy Control Board (AECB), the federal nuclear regulatory agency concerned with health and safety, and protection of the environment. Smoke detectors are approved by the AECB on a model by model basis. It is illegal to sell an ionization-type smoke detector in Canada that has not received AECB approval.

The AECB has determined that smoke detectors must comply with the radiation safety limits governing other consumer products that are potential radiation emitters, such as colour television sets. Smoke detectors must also be designed to make it very difficult using ordinary household tools to tamper with the device and get at the radiation source. The ionization chamber mechanism must be able to withstand all but the most willful damage.

There are also specific technical standards and tests for the sealed sources themselves. For example, the amount of radioactive material that may be present is limited, and the source must pass performance tests which duplicate conditions that might be encountered through accident or misuse.

The trefoil radiation warning symbol must be attached to the housing containing the radiation source in all ionization chamber smoke detectors approved for sale in Canada. The trefoil is attached to inform users that radioactive material is present, and to discourage people from tampering with, or dismantling the unit. The radiation symbol serves a warning purpose similar to the skull-and-crossbones label on a bottle containing a poison.



How should you dispose of old smoke detectors?

The residential models of ionization chamber smoke detectors may be thrown in the garbage. At one time, the Atomic Energy Control Board required that home smoke detectors be disposed of in controlled waste areas. In 1978, however, the Board reviewed its disposal policy in light of an international study by radiation safety experts which determined that domestic smoke detectors thrown out with the regular garbage were not a concern with respect to the health and safety of the public or waste disposal workers.

Some older units still in use carry an out-dated warning label stating that the smoke detector should be returned to the supplier or manufacturer, or that the AECB should be contacted when the unit is no longer wanted and is about to be discarded. This does not apply now.

Ionization chamber smoke detectors designed for industry, however, use a somewhat larger radiation source in order to withstand higher dust and grit interference. Industrial smoke detectors also have a more open design. These types of smoke detectors are not available for use in homes, and the AECB still requires that they be discarded in accordance with approved methods for the disposal of low-level radioactive waste.

Shouldn't the outer package have a radiation warning sign?

This question relates to the ability of the buyer to tell one type of smoke detector from another without opening the box or the device itself. But like the poison symbol the radiation warning sign is a distinct cautionary or hazard notice, not a consumer-oriented content label, and it would not be appropriate - in fact it would be misleading - to place it on other than the source housing itself, for example on removable parts or on the shipping carton. Regulations on the use of the radiation warning symbol are very specific, and in view of the tiny quantity of radioactive material involved and its nature, placing the symbol on the outer box is not called for. There is even some question whether the trefoil symbol should be required at all. The international study which led to Canada's lifting of disposal restrictions for domestic ionization chamber smoke detectors suggested the marking might be replaced with the words, "This smoke detector contains radioactive material which presents no significant hazard to health if used in accordance with the instructions."

Further reading:

"Smoke Detectors," *Canadian Consumer*, October 1975.

"Are Smoke Detectors Safe?" *Consumer Reports*, January 1977.

"Smoke Detectors," *Consumer Reports*, October 1984.

"Recommendations for Ionization Chamber Smoke Detectors In Implementation of Radiation Protection Standards", OECD Nuclear Energy Agency, Committee on Radiation Protection and Public Health, Expert Group on Safety Standards for Smoke and Fire Detectors, 1977.

J. Rundo, W.D. Fairman, M. Essling and D.R. Huff, "Ingestion of 241-Am Sources Intended for Domestic Smoke Detectors: Report Of A Case", *Health Physics*. Vol. 33, December 1977.

"Environmental Assessment of Ionization Chamber Smoke Detectors Containing Am-241", United States Nuclear Regulatory Commission, NUREG/CR-1156, 1979.

"An Assessment of Radiation Doses from Residential Smoke Detectors That Contain Americium-241", Oak Ridge National Laboratory, October 1981.

Ionizing Radiation: Sources and Biological Effects. United Nations Scientific Committee on Effects of Atomic Radiation, New York, N.Y. 1982.

"Smoke Detection: A Status Report", Division of Building Research, National Research Council of Canada, February 1984.

P. Globus and J.R. Klatt, "The home appliance that can save your life," *Reader's Digest*, September 1985.

M.A. Sultan and W.M. Feldman, "Smoke Alarms in the Home: What Every Physician Should Know", Division of Building Research, National Research Council of Canada,; reprint from the Canadian Medical Association Journal, Dec. 15, 1985.

The risk

Ionization-type smoke detectors contain a radioactive material. Their use results in exposure of people to very low levels of radiation. It is known that radiation exposure brings with it a risk of cancer and possible genetic effects, with the risk increasing as the amount of exposure increases.

The U.S. Nuclear Regulatory Commission funded a study which looked at the health effects of 14 million ionization chamber smoke detectors, enough to service about 21 million people. The useful life was assumed to be 10 years, and disposal was by either sanitary landfill or incineration.

Analysis showed that the risk to the exposed population over a 10-year period was about 0.1 fatal cancer. The normally-occurring cancer mortality rate for a group of 21 million people in Canada is about 37,000 per year.

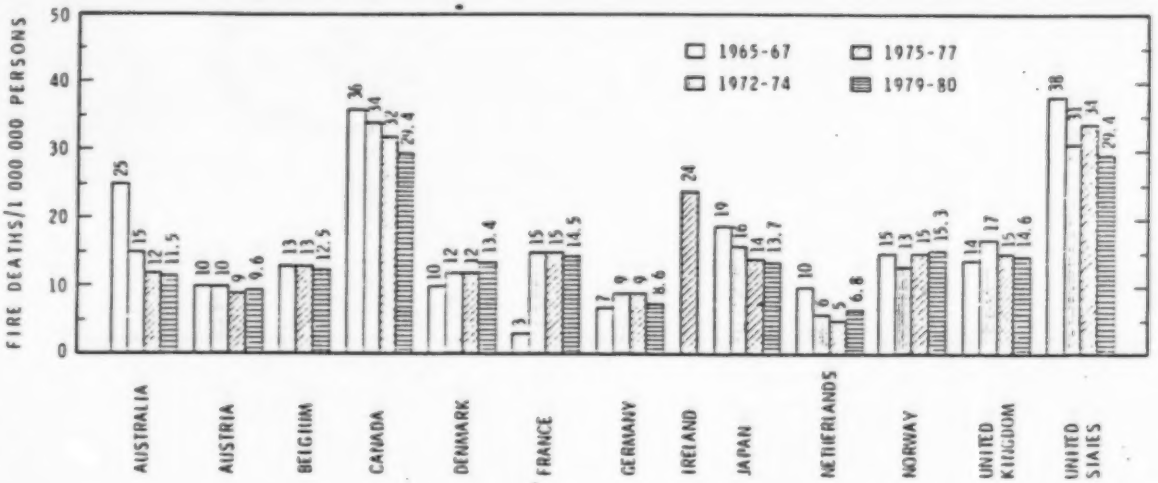
A comparison of these numbers illustrates the relatively small risk involved in using ionization chamber smoke detectors. Furthermore, the 37,000 cancer deaths per year are actual deaths while the 0.1 fatal cancer over 10 years of smoke detector use was calculated using conservative assumptions. The ratio of potential lives saved by early warning of fires, compared to possible fatal cancers due to the use of ionization-type smoke detectors ranges from 15,000 to 51,000.

- based on NUREG/CR-1156 "Environmental Assessment of Ionization Chamber Smoke Detectors Containing Americium-241"

The benefits

According to the National Research Council and other agencies involved in fire safety:

* Canada ranks near the top of the list of Western countries in fire deaths each year.
* If you install a smoke detector in your home, you double your chances of surviving a fire.
* If you live in a mobile home, the odds of your surviving a fire go up 400% when a smoke detector is present.
* In the case of fires related to smoking -- the single biggest cause of residential fires -- smoke detectors cut the death rate by 75%.
* Smoke detectors give the first warning of a fire's presence in about 40% of home fires.
* It is estimated that 40% to 50% of the people killed in fires each year could be saved if adequate early-warning detection devices were installed.
* Ionization chamber smoke detectors react relatively quickly to fast-burning, flaming fires.
* The ionization-type detector may have advantages for the consumer in terms of cost and reliability.



CHANGE IN LIFE EXPECTANCY DUE TO VARIOUS CAUSES

Increase in Life Expectancy

Cause	Days
Mobile coronary care units	125
Air bags in car	50
Smoke alarm in home	10
PAP Test	4

Loss of Life Expectancy

Cause	Days
Being unmarried - male	3500
Cigarette smoking	2250
Heart disease	2100
Being unmarried - female	1600
Cancer	980
20% Overweight	900
Low socioeconomic status	700
Stroke	520
Cigar smoking	330
Dangerous job - accidents	300
Pipe smoking	220
Increasing food intake 100 cal/day	210
Motor vehicle accidents	207
Pneumonia - influenza	141
Alcohol	130
Accidents in home	95
Diabetes	95
Legal drug misuse	90
Average jobs - accidents	74
Drowning	41
Job with radiation exposure	40
Falls	39
Accidents to pedestrians	37
Safest jobs - accidents	30
Fires - burns	27
Generation of energy	24
Poison	17
Suffocation	13
Natural radiation	8
Medical X-rays	6
Coffee	6
Oral contraceptives	5
Accidents to pedalcycles	5
All catastrophes combined	3.5
Diet drinks	2
Radiation from nuclear industry	0.02

Source: NUREG/CR-1156, "Environmental Assessment of Ionization Chamber Smoke Detectors Containing Americium-241"

As the table indicates, a cigar smoker's life, on average, is shortened by a year, while the existence of mobile coronary care units lengthens life expectancy by a third of a year for people living near them. Smoke detectors also marginally improve users' life expectancy.